BAYOU VERRET, BAYOU CHEVREUIL, BAYOU CITAMON, AND GRAND BAYOU TMDL FOR BIOCHEMICAL OXYGEN-DEMANDING SUBSTANCES

SUBSEGMENT 020101

REVISED TMDL REPORT

May 5, 2004

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REVISED TMDL REPORT

By:
FTN Associates Ltd.

For:
Engineering Group 2
Environmental Technology Division
Office of Environmental Assessment
Louisiana Department of Environmental Quality

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EXECUTIVE SUMMARY

This report presents the results of calibrated dissolved oxygen (DO) modeling and total maximum daily load (TMDL) calculations for subsegment 020101 (Bayou Verret, Bayou Chevreuil, Bayou Citamon, and Grand Bayou). The modeling was conducted to establish a TMDL for biochemical oxygen-demanding pollutants for this subsegment. Subsegment 020101 is located in southern Louisiana in the Barataria basin west of New Orleans and covers approximately 281 square miles. The primary land uses are wetland forest and agriculture. No point source discharges were included in the model, but several small point source discharges within the subsegment were included in the TMDL.

Inputs for the calibration model were developed from data collected during the June 2003 intensive survey, data collected by the Louisiana Department of Environmental Quality (LDEQ) at one monitoring station in the watershed, the LDEQ Reference Stream Study, and NPDES permits and permit applications for each of the point source dischargers. A satisfactory calibration was achieved for the model. In those cases where the calibration was not as accurate, the difference was in the conservative direction. For the projection models, data were taken from current discharge permits, current applications, and ambient temperature records. The Louisiana TMDL Technical Procedures manual (dated 09/23/2003) has been followed in this study.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen and the available data was limited to low flow conditions. The model used was LA-QUAL, a modified version of QUAL-TX, which has been adapted to address specific needs of Louisiana waters.

Subsegment 020101 was listed as impaired on both the EPA 1999 Court Ordered 303(d) list for Louisiana and the LDEQ Final 2002 303(d) list. The subsegment was found to be not supporting its designated use of fish and wildlife propagation. Subsegment 020101 was subsequently scheduled for TMDL development with other listed waters in the Barataria basin. According to the 1999 Court Ordered 303(d) list, the suspected causes of impairment included organic enrichment / low DO and nutrients; and the suspected sources were municipal point sources, package plants (small flows), collection system failure, inflow and infiltration, domestic wastewater lagoon, land disposal, septic tanks, other, natural sources, unknown source, and non-irrigated crop production. This TMDL addresses the organic enrichment / low DO impairment and the nutrient impairment.

Based on the results of the projection modeling, meeting the water quality standard for DO of 5.0 mg/L will require man made sources to be reduced by 100% in summer and 98% in winter and natural background sources will have to be reduced by 46% in the summer. The no-load scenarios (i.e., no reduction in natural background sources) yielded minimum DO values of 3.0 mg/L for summer and 5.5 mg/L for winter. This suggests that the existing DO standard for subsegment 020101 is definitely not appropriate for summer.

Nonpoint source load calculations and TMDL calculations were performed using LDEQ's standard TMDL spreadsheet. This spreadsheet calculates wasteload allocations (WLAs) for point sources, load allocations (LAs) for man-made nonpoint sources and natural nonpoint sources, and incorporates an explicit margin of safety (MOS). For this TMDL, the explicit MOS was set to 20% of the sum of the man-made nonpoint sources and the point sources. This MOS accounts for future growth as well as lack of knowledge concerning the relationship between pollutant loads and water quality. The explicit MOS is provided in addition to the implicit MOS, which is created by conservative assumptions in the modeling. A summary of the TMDL is provided in Table ES.1.

Table ES.1. TMDL for Subsegment 020101 (Sum of CBODu, NBODu, and SOD).

	Summer (May-Oct)		**Winter (Nov-Apr)**	
	Reduction	**Load (kg/day)**	**Reduction**	**Load (kg/day)**
Point Source WLA	0%	7	0%	7
Point Source Reserve MOS (20%)		2		2
Natural Nonpoint Source LA	46%	2321	0%	3091
Natural Nonpoint Source MOS (0%)		0		0
Man-made Nonpoint Source LA	100%	0	98%	49
Man-made Nonpoint Source MOS (20%)		0		12
TMDL	--	2330	--	3161

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters.

This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

This TMDL was developed by FTN Associates, Ltd. with assistance from numerous LDEQ personnel, as well as several other people. The LDEQ project manager was Emelise Cormier and the FTN project manager was Philip Massirer. The guidance and assistance from Ms. Cormier throughout this project was extremely valuable. Other LDEQ personnel that provided valuable guidance at various times were Dick Duerr and Marian Aguillard.

Several field reconnaissance trips were made by LDEQ watershed survey personnel. A reconnaissance survey was performed by Philip Massirer of FTN, Dick Duerr of LDEQ, and several LDEQ watershed survey personnel.

The intensive survey was performed by LDEQ watershed survey personnel and the laboratory analyses of water samples were performed by LDEQ laboratory personnel. Initial compilation of some of the field data was done by LDEQ watershed survey personnel.

The field data analysis, water quality modeling, TMDL calculations, and preparation of the report were performed by several FTN personnel including Richard Bennett, Christine Richmond, and Philip Massirer.

ABBREVIATIONS

BMP	best management practice
BOD	biochemical oxygen demand
CBODu	ultimate carbonaceous biochemical oxygen demand
CFR	Code of Federal Register
cfs	cubic feet per second
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
DO	dissolved oxygen
EPA	Environmental Protection Agency
FTN	FTN Associates, Ltd.
ft/sec	feet per second
$g/m^2/day$	grams per square meter per day
kg/day	kilograms per day
km	kilometer
LA	load allocation
LAC	Louisiana Administrative Code
lbs/day	pounds per day
LC	loading capacity
LDEQ	Louisiana Department of Environmental Quality
LDNR	Louisiana Department of Natural Resources
LTP	Louisiana TMDL Technical Procedures Manual
MGD	million gallons per day
NBODu	ultimate nitrogenous biochemical oxygen demand
NCM	nonconservative material
NPDES	National Pollutant Discharge Elimination System
mg/L	milligrams per liter
TMDL	total maximum daily load
USGS	United States Geological Survey
WLA	wasteload allocation

1. Introduction

This report presents a total maximum daily load (TMDL) for biochemical oxygen demanding substances for subsegment 020101 (Bayou Verret, Bayou Chevreuil, Bayou Citamon and Grand Bayou). This subsegment was listed as impaired on both the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999) and the Louisiana Department of Environmental Quality (LDEQ) Final 2002 303(d) List (LDEQ 2003a). On both of these 303(d) lists, organic enrichment/low dissolved oxygen (DO) and nutrients were cited as suspected causes of impairment. Therefore, development of a TMDL for biochemical oxygen demanding substances was required. A calibrated water quality model was developed and projections were simulated to quantify the load reductions which would be necessary in order for this subsegment to comply with established water quality standards and criteria. The TMDL in this report was developed in accordance with the LDEQ TMDL Technical Procedures Manual (known as the "LTP") (LDEQ 2003b) as well as federal requirements in Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

2. Study Area Description

2.1 General Information

Subsegment 020101 is located in southern Louisiana in the Barataria basin west of New Orleans (see Figure A.1 in Appendix A). This subsegment includes three main bayous (Bayou Verret, Bayou Citamon, and Bayou Chevreuil) and several other significant canals and bayous (including Baker Canal and St. James Canal). Although Grand Bayou is included in the name of subsegment 020101, it is actually located in an adjacent subsegment.

Subsegment 020101 is bounded on the north by the natural ridge along the Mississippi River and on the west and south by the natural ridge along Bayou Lafourche. The overall drainage pattern for this subsegment is from west to east, with most of the water draining into Lac des Allemands. However, some of the water in Bayou Citamon can leave the subsegment through Grand Bayou. There are currently no flow control structures in this subsegment (e.g., pump stations, dams, etc.). However, the feasibility of diverting Mississippi River water into this subsegment via St. James Canal or Dredgeboat Canal is currently being evaluated by state and federal agencies through a Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) project.

This subsegment has a drainage area of 281 mi^2 (727 km^2). The two predominant land uses in this subsegment are wetland forest and agriculture. Land use data for this subsegment are summarized in Table 2.1 and shown spatially on Figure A.2 (in Appendix A). Most of the agricultural land (and other developed land) is located near the ridges along the northern, western, and southern edges of the subsegment. The primary crop in this area is sugarcane.

Table 2.1. Land use for subsegment 020101.

Land Use Type	**Percent of Total Area**
Freshwater Marsh	2.1%
Saline Marsh	0.0%
Wetland Forest/Deciduous	51.7%
Upland Forest/Mixed	0.2%
Wetland Scrub/Shrub Deciduous	0.6%
Wetland Scrub/Shrub Evergreen	0.1%
Agriculture/Cropland/Grassland	36.8%
Vegetated Urban	4.0%
Non-vegetated Urban	0.1%
Upland Barren	0.3%
Water	4.1%
TOTAL	100.0%

2.2 Water Quality Standards

The designated uses and numeric water quality standards for subsegment 020101 are listed below in Table 2.2. This subsegment has a year round DO standard of 5.0 mg/L.

Table 2.2. Water quality numeral criteria and designated uses (LDEQ 2003c).

Subsegment Number	020101
Subsegment Name	Bayou Verret, Bayou Chevreuil, Bayou Citamon and Grand Bayou
Designated Uses	A, B, C, F
Criteria:	
DO	5.0 mg/L
Chloride	65 mg/L
Sulfate	50 mg/L
pH	6.0 – 8.5
Bacteria	see note 1 below
Temperature	32 °C
TDS	430 mg/L

USES: A – primary contact recreation; B – secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

Note 1 – 200 colonies / 100 mL maximum log mean and no more than 25% of samples exceeding 400 colonies / 100 mL for May through October; 1000 colonies / 100 mL maximum log mean and no more than 25% of samples exceeding 2000 colonies / 100 mL for November through April.

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. The LDEQ antidegradation policy (LAC 33: IX.1109.A) includes the following statements that are applicable to this TMDL: "No lowering of water quality will be allowed in waters where standards for the designated water uses are not currently being attained. ... The administrative authority will not approve any wastewater discharge or certify any activity for federal permit that would impair water quality or use of state waters." The TMDL in this report is consistent with the LDEQ antidegradation policy.

2.3 Point Sources

A total of seven National Pollutant Discharge Elimination System (NPDES) permits were identified for point source discharges within subsegment 020101. Information for these point source discharges is shown in Table 2.3. This information was obtained by reviewing data from the LDEQ point source database. The locations of these facilities are shown on Figure A.3 (in Appendix A). Because none of these facilities discharges directly into the modeled stream reaches, they were not included in the model.

2.4 Nonpoint Sources

Suspected nonpoint sources for subsegment 020101 have been listed in the 1999 Court Ordered 303(d) List for Louisiana (EPA 1999). These sources include collection system failure, inflow and infiltration, land disposal, septic tanks, natural sources, and non-irrigated crop production. Based on LDEQ's experience in the Barataria basin, it is suspected that there is considerable nonpoint oxygen demand in this subsegment that is natural (i.e., not induced by human activities).

2.5 Water Quality Conditions/Assessment

As mentioned in Section 1, this subsegment was listed as impaired by both EPA and LDEQ due to organic enrichment / low DO and nutrients. The 303(d) listing is shown below in Table 2.4. The water quality data that LDEQ used to assess this subsegment and include it on the 303(d) list were ambient water quality monitoring data collected at LDEQ station 0084 (Bayou Chevreuil near Chegby (Chackbay), Louisiana). The location of this monitoring station is shown on Figure A.1. Data were collected at this station between March 1978 and December 2000 at monthly or bimonthly intervals. As shown in Table B.1 (in Appendix B), 183 of the 202 DO measurements (89%) were below the water quality standard of 5.0 mg/L.

Table 2.3. Information for point source discharges in subsegment 020101.

File Number	Company	Facility	UTM Coordinates	Facility Type	Location	Receiving Water	Expected flow (MGD)	BOD5 (mg/L)	Modeling comments
LAG540340 WG020847	GREENBRIAR SEWER INC	GREENBRIAR SUBD.	3320819.59568 688394.17644			BAYOU VERRET	0.012	avg 30	Not in model but in TMDL
LAG530914	BOH CONST CO	IMC AGRICO FAUSTINA PLT	3330054.71129 700381.52321	SANITARY D/C ONLY	ST JAMES 9959 HWY 18	St James Ph Canal thence to Bayou Verret	0.0002	max 45	Not in model but in TMDL
LAG540673	ST JAMES FACILITIES CORP	ST JAMES YOUTH CTR	3331017.51151 692486.29922	YOUTH DETENTION & REHAB CENTER	"DONALDSONVILLE 10565 YOUTH CNTR DR"	Unnamed ditch to Bayou Verret	0.0111	avg 30, max 45	Not in model but in TMDL
LAG540680	ST JAMES PH HOUSING AUTHORITY	HYMEL HOUSING PROJ/WELCOME	3327233.75729 705454.73704	STP	8234 Mill Street, James, LA 70086	Local drainage to Bayou Chevreuil	0.0147	avg 30, max 45	Not in model but in TMDL
LAG560016	ABBY SANITARY SEWERAGE CORP	ABBY PLANTATION MHP	3304456.29959 706105.72376	OXIDATION POND FOR A MOBILE HOME PARK	THIBODAUX, ABBY ROAD	ST. JAMES CANAL	0.036	avg 20	Not in model but in TMDL
LA0000035	CALDWELL SUGARS COOPERATIVE, INC.	CALDWELL SUGAR MILL	3299903.29639 709128.73229	SUGAR MILL WASTEWATER IMPOUNDMENT	"THIBODAUX, 1275 LA HWY 304"	GRAND BAYOU	0.72	avg 10	Not in model but in TMDL
LAG530788	TEXAS FUEL & ASPHALT CO INC	EAGLE ASPHALT PROD	3331539.29561 700541.67674	ASPHALT BLENDING & STORAGE	DONALDSONVILLE HWY 18 @ SUNSHINE BR	Local drainage to Bayou Verret		max 45	Not in model but in TMDL

Table 2.4. 303(d) listing for subsegment 020101.

Subsegment	Description	Suspected sources	Suspected causes	Priority ranking (1=highest)
020101	Bayou Verret, Bayou Chevreuil, Bayou Citamon and Grand Bayou	Municipal point sources Package plants (small flows) Collection system failure Inflow and infiltration Domestic Wastewater lagoon Land disposal Septic tanks Other Natural sources Unknown source Non-Irrigated crop production	Mercury Organic enrichment/low DO Pathogen indicators Pesticides Oil & Grease Suspended solids Turbidity Noxious aquatic plants Nutrient	3

2.6 Previous Studies and Data

No previous water quality studies have been identified for subsegment 020101. There are no US Geological Survey (USGS) or Corps of Engineers stage gages or flow gages in the subsegment. The only historical water quality data that are known to exist are the LDEQ data mentioned in Section 2.5.

3. Field Survey

An intensive field survey was conducted by LDEQ personnel in subsegment 020101 during the week of June 2-6, 2003. The purpose of this survey was to gather information about the subsegment and collect data that would be needed to set up and calibrate a water quality model. The field data that were collected included water quality samples and in situ measurements, continuous in situ monitoring, cross sections, acoustic Doppler flow measurements, drogue measurements, and two dye studies for time of travel. Continuous in situ monitoring data (temperature, DO, pH, and specific conductivity) were collected from June 3 to June 5. Water quality samples and associated in situ data were taken on June 4. Maps and descriptions of the field data collection sites are included in Appendix C1.

3.1 Water Quality Sampling and In Situ Data

The water quality sampling data and the in situ data collected with the water quality samples are shown in Table C2.1 (in Appendix C2). Only two of the 12 stations had DO readings above the water quality standard of 5.0 mg/L (GB-1 and LDA-1); both of those stations were actually outside of subsegment 020101. Table C2.2 shows shows a comparison of data collected at BCh-2 during the survey with LDEQ historical data collected during the month of June at station 0084 (same location as BCh-2). This comparison shows that in general, the survey data appear to be representative of early summer conditions in this system.

3.2 Continuous Monitoring Data

Figures C3.1 through C3.72 (in Appendix C3) show plots of the continuous in situ data collected during the survey. The diurnal fluctuations of DO ranged from about 1.5 mg/L to about 3.0 mg/L at all stations except BCi-2, BV-1, and LDA-1, where the diurnal fluctuations of DO were about 4-5 mg/L. DO percent saturation levels exceeded 100% at only one station (LDA-1). Diurnal fluctuations of pH were small (<0.5 su) at all stations except at LDA-1, where the diurnal fluctuation exceeded 2.0 su. The absence of large DO fluctuations and supersaturated DO values suggest that algal productivity is low at stations within the subsegment (station LDA-1 is outside the subsegment). The continuous conductivity data showed some variability, but there were no obvious explanations for the variations. For example, the conductivity at BV-1 increased from about 414 µmhos to 642 µmhos over a period of 36 hours, but the data at the other stations did not reflect that pattern. For example, over that same 36 hour period, the conductivity at BCi-2 decreased from about 272 µmhos to 214 µmhos. Continuous water level data were also measured, but they did not show any significant diurnal fluctuations. However, the water level at the mouth of Bayou Chevreuil (BCh-6) showed an overall increase of about 0.1 m (0.3 ft) from June 3 to June 5.

3.3 BOD Time Series Analyses

Results of 60-day BOD time series analyses are shown in Appendix C4. For each sample, values of cumulative oxygen demand and NO2+NO3 concentration were obtained at selected intervals over a period of about 60 days. These data were entered into an LDEQ spreadsheet called GSBOD, which contains algorithms for fitting first order curves to the data to calculate values of ultimate carbonaceous biochemical oxygen demand (CBODu), ultimate nitrogenous biochemical oxygen demand (NBODu), decay rates for both CBODu and NBODu, and lag times for both CBODu and NBODu. The results of these analyses are shown in Appendix C4. The NBODu decay rates for the main stem stations were slightly increasing from upstream to downstream. The CBODu decay rates showed little spatial variability.

3.4 Cross Section Data

Cross sections were measured at 11 water quality sampling locations and 16 other locations for the dye studies. These cross section data are shown in Appendix C5.

3.5 Velocity and Flow Measurements

Table C6.1 (in Appendix C6) shows acoustic Doppler and manual flow measurements made at the sampling sites. All of the measured flows were positive (i.e., flow towards Lac des Allemands) except at BCi-4 on June 4. For stations where measurements were taken on both June 3 and June 4, the flows were consistently lower on June 4 than on June 3. This temporal pattern is consistent with the increase in water levels at BCh-6 between June 3 and June 5 (i.e., increasing water levels in Lac des Allemands will cause increased backwater and retard the flow in the Bayou Chevreuil system).

Table C6.2 (in Appendix C6) shows velocity measurements made with drogues and flows that were estimated from those velocities. Except for several measurements that were influenced by the wind, most of the measurements and field notes indicated downstream flow (i.e., towards Lac des Allemands) on June 3 and June 4.

Two dye studies were conducted to measure velocity in this system. One slug of dye was injected in Bayou Citamon near BCi-2 and another was injected in Bayou Chevreuil near BCh-2. Appendix C6 contains time of travel calculations (Tables C6.3 and C6.4) as well as plots of dye concentration versus time at these two locations (Figures C6.1 and C6.2). In both dye studies, the dye moved downstream throughout the duration of the dye studies. Although the dye studies indicated no diurnal flow reversals, the velocities were significantly lower on June 5 than on June 4. This is consistent with the water level data and the drogue and flow measurements, all of which indicated decreasing flow from June 3 to June 5.

3.6 Dispersion Coefficients

The results of the dye studies mentioned in Section 3.5 were also used to calculate dispersion coefficients by fitting theoretical curves of dye concentration vs. distance to the observed data (the dispersion coefficient was adjusted so that the shape of the theoretical curve was similar to the observed data). Table C7.1 shows a summary of the dispersion coefficients and Tables C7.2 through C7.6 show calculations for each dye run. Figures C7.1 through C7.5 show comparisons of the theoretical dye curves and the observed data.

4. Documentation of Calibration Model

4.1 Program Description

"Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs). ... Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or near shore ocean areas. ... Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios. ... A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system." (EPA841-B-97-006, pp. 1-30)

The model used for this TMDL was LA-QUAL, a steady-state one-dimensional water quality model. LA-QUAL has the mechanisms for incorporating hydraulic characteristics of Louisiana waterbodies and was particularly suitable for use in modeling Main Canal. LA-QUAL history dates back to the QUAL-I model developed by the Texas Water Development Board with Frank D. Masch & Associates in 1970 and 1971. William A. White wrote the original code.

In June, 1972, EPA awarded Water Resources Engineers, Inc. (now Camp Dresser & McKee) a contract to modify QUAL-I for application to the Chattahoochee-Flint River, the Upper Mississippi River, the Iowa-Cedar River, and the Santee River. The modified version of QUAL-I was known as QUAL-II.

Over the next three years, several versions of the model evolved in response to specific client needs. In March, 1976, the Southeast Michigan Council of Governments (SEMCOG) contracted with Water Resources Engineers, Inc. to make further modifications and to combine the best features of the existing versions of QUAL-II into a single model. That became known as the QUAL-II/SEMCOG version.

Between 1978 and 1984, Bruce L. Wiland with the Texas Department of Water Resources modified QUAL-II for application to the Houston Ship Channel estuarine system. Numerous modifications were made to enable modeling this very large and complex system including the addition of tidal dispersion, lower boundary conditions, nitrification inhibition, sensitivity analysis capability, branching tributaries, and various input/output changes. This model became known as QUAL-TX and was subsequently applied to streams throughout the State of Texas.

In 1999, LDEQ and Wiland Consulting, Inc. developed LA-QUAL based on QUAL-TX Version 3.4. The program was converted from a DOS-based program to a Windows-based program with a graphical interface and enhanced graphic output. Other program modifications specific to the needs of Louisiana and the LDEQ were also made. LA-QUAL is a user-oriented model and is intended to provide the basis for evaluating total maximum daily loads in the State of Louisiana.

The development of a TMDL for dissolved oxygen generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and dissolved oxygen and various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants in to the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams which can be used to gauge the relative health of the watershed is also collected.

Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions which have actually been measured in the watershed. The findings are then input to the model. Best professional judgment is used to determine initial estimates for parameters which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of the dissolved oxygen, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see if the calibration holds for both sets of data. When this happens, the model is said to be verified.

Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that dissolved oxygen criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the nonpoint source pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams.

4.2 Input Data Documentation

Data collected during the June 2003 intensive survey (described in Section 3) were used to establish the input for the model calibration. This survey was conducted during a period of low flows and warm temperatures.

The flows in the model were determined based on dye study results, selected drogue measurements, and acoustic Doppler flows. Flow calculations are discussed in Section 4.2.11. A simulation of conservative constituents (e.g., chloride and conductivity) was performed to check the flow balance as discussed in Section 4.3.1.

Field and laboratory water quality data were entered in a spreadsheet for ease of analysis. The Louisiana GSBOD program was applied to the BOD time series data in a separate spreadsheet as described in Section 3. The survey data were the primary source for the model input data for initial conditions, decay rates, and inflow water quality.

4.2.1 Model Schematics and Maps

A vector diagram of the modeled area is presented in Appendix D and in Figure 4.1. The vector diagram shows the locations of survey stations, the reach design, the location of the modeled tributaries, and the locations of inflows. The reach design is discussed in Section 4.2.5. Maps showing the entire subsegment are included in Appendix A.

4.2.2 Model Options, Data Type 2

Five constituents were modeled during the calibration process. These were chlorides, conductivity, dissolved oxygen (DO), CBODu, and NBODu. The chlorides and conductivity were included in the model for the purpose of checking the flow balance. NBODu was represented in the model as nonconservative material (NCM).

4.2.3 Program Constants, Data Type 3

Two program constants were specified in the model input. First, the hydraulic calculation method was specified as 2 rather than 1. Method 2 is the preferred method and allows the user to input widths and depths rather than velocities and depths. The other program constant that was specified was the NCM oxygen uptake rate, which was set to 1.0 mg of oxygen consumed per mg of NCM decayed.

4.2.4 Temperature Correction of Kinetics, Data Type 4

The temperature values in the model are used to correct the rate coefficients in the source/sink terms for the other water quality variables. These coefficients are input at 20°C and are then corrected to the stream temperatures using the following equation:

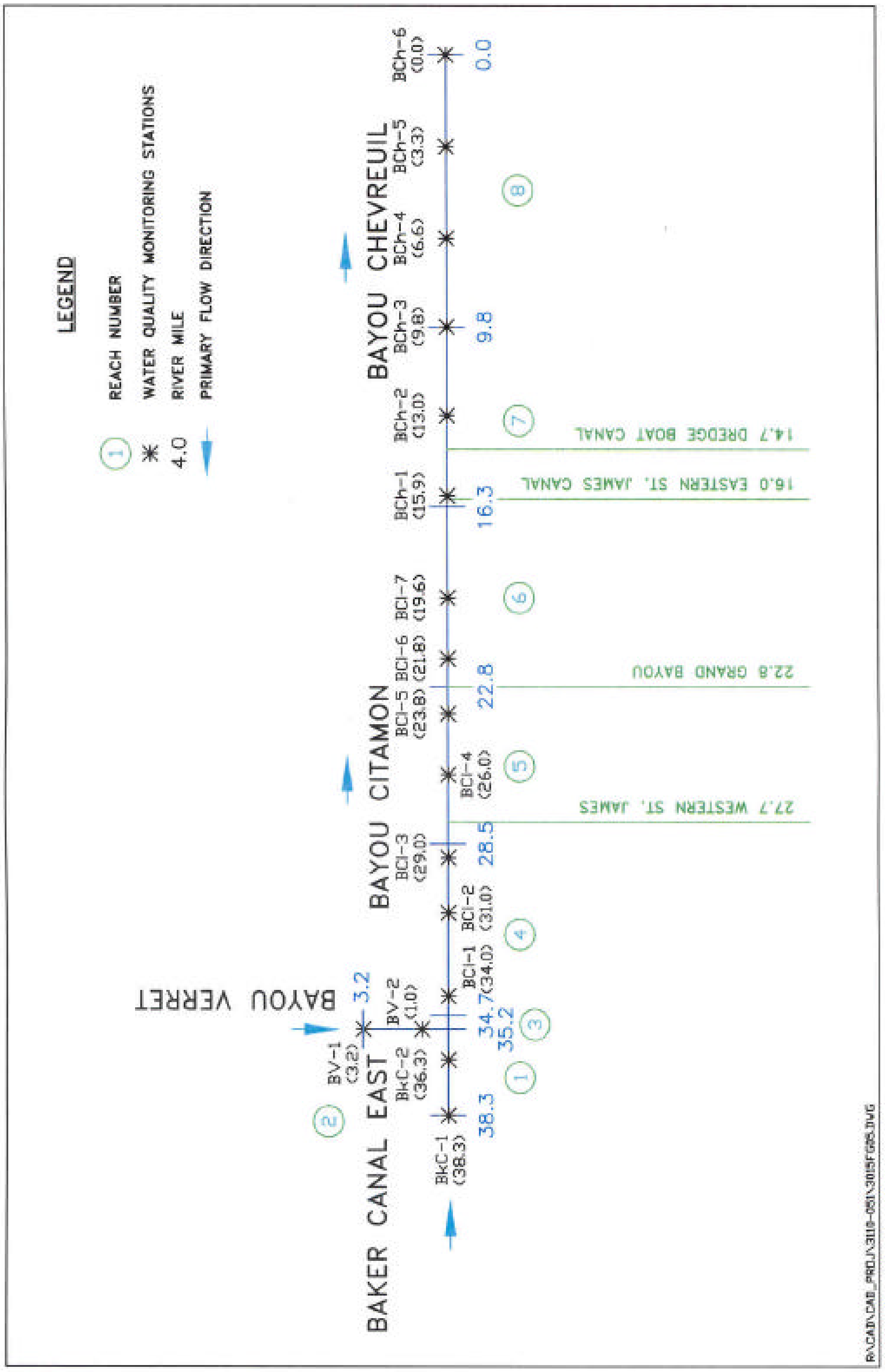

Figure 4.1 LA-QUAL Vector Diagram

$X_T = X_{20} * Theta^{(T-20)}$

where:

X_T = the value of the coefficient at the local temperature T in degrees Celsius
X_{20} = the value of the coefficient at the standard temperature (20 degrees Celsius)
Theta = an empirical constant for each reaction coefficient

In the absence of specified values for data type 4, the model uses default values. The default theta values include 1.047 for CBOD decay, 1.070 for nonconservative material (NBOD) decay, and 1.065 for SOD. All three of these default values were consistent with the LTP (LDEQ 2003b), so no values were explicitly specified in data type 4.

4.2.5 Reach Identification Data, Data Type 8

The main stem of the model includes all of Baker Canal East, Bayou Citamon, and Bayou Chevreuil. Part of Bayou Verret is modeled as a branch of the main stem. A vector diagram of the model is shown in Appendix D.

The system being modeled was divided into a total of eight reaches based on changes in width and depth. The element size was approximately 0.10 km throughout the model. The widths and depths are discussed in Section 4.2.6.

4.2.6 Hydraulic Coefficients, Data Types 9 and 10

The hydraulics were specified in the model input for the LA-QUAL model using the power functions (width = a * Q^b + c and depth = d * Q^e + f). Values specified in the model for these power functions are shown in Table E.1 in Appendix E. Based on the low gradient of streams in this subsegment and hydraulic conditions during the intensive field survey, it was assumed that changes in the stream flow rate between the calibration and projection simulations would create only negligible changes in depths and widths. Therefore, the coefficients and exponents (a, b, d, and e) were set to zero and the constants (c and f) were set based on the widths and depths from measured cross sections. Plots of modeled and observed depths and widths are shown in Appendix F.

Dispersion was specified in the model using the dispersion coefficients calculated in Section 3.6. For each dye study, the coefficient from the last run was used since it reflected dispersion over the longest time interval. The dispersion coefficients used in the model are shown in Table E.1 in Appendix E.

4.2.7 Initial Conditions, Data Type 11

The initial conditions were used to specify the temperature and salinity for each reach and reduce the number of iterations required by the model for constituents being simulated. The values required for this model were temperature, salinity, and DO by reach. The input values came from the survey station(s) located closest to the reach or from an average of samples taken from stations located within the reach. For DO, the initial values were set to the calibration targets. The model inputs and data sources for the initial conditions are shown in Table E.2 in Appendix E.

Although chlorophyll data were available from the intensive survey, chlorophyll values were not specified in the initial conditions because the effects of algae on DO were taken into account through the determination of calibration target values for DO (discussed in Section 4.3.2).

4.2.8 Reaeration Rates, Data Type 12

For reaeration, the Louisiana equation (option 15) was used for Bayou Verret because its depth (0.72 m) and velocity (0.02 to 0.03 m/sec) were within the range of values for which the Louisiana equation was developed (depth = 0.3 ft to 3.0 ft and velocity = 0.02 ft/sec to 0.8 ft/sec; LDEQ 2003b). For all other reaches, the O'Connor-Dobbins equation (option 3) was used because the depths were greater than 3.0 ft but within the range of depths for which the O'Connor-Dobbins equation was developed (1 ft to 30 ft; LDEQ 2003b).

4.2.9 SOD, Data Type 12

The SOD values were achieved through calibration and ranged from 1.0 g/m^2/day to 3.5 g/m^2/day. The SOD values used in the model are shown in Table E.5 in Appendix E. Results of the water quality calibration are discussed in Section 4.3.2.

4.2.10 CBODu and NBODu Rates, Data Types 12 and 15

The CBODu and NBODu decay rates used in the model were based on values calculated by the LDEQ spreadsheet GSBOD for each station. Because the measured NBODu decay rates along the main stem were slightly higher towards the downstream end of the model than at the upstream end, the decay rates for both CBODu and NBODu were based on averages of values within selected groups of reaches. The individual decay rates are summarized in Table C4.1 (Appendix C4) and the values used in the model are shown in Table E.3 (Appendix E).

CBODu and NBODu settling rates were not used in the model because there was no information suggesting that simulating CBODu or NBODu settling was necessary. There were no point source discharges or other inflows that are known to be high in particulate CBODu or NBODu. The effects of settled CBODu and NBODu on DO are already implicitly included in the SOD.

4.2.11 Flow Calculations

The flows that were either measured directly or estimated from drogue velocities on June 4 (discussed in Section 3.5) were used to compute a flow balance for the system. The general approach for developing this flow balance can be summarized in the following steps (calculations are shown in Appendix G):

1. Determine inflows from headwaters
2. Determine inflows and outflows from tributaries and distributaries

3. Determine total flow needed near the downstream end of the system
4. Calculate incremental inflow needed to balance the flows

The headwater inflows were determined from a drogue measurement for Bayou Verret and from a conductivity mass balance for Baker Canal East. A drogue measurement was made for Baker Canal East on June 4, but the measurement was influenced by an east wind that pushed the drogue upstream. Therefore, the conductivity mass balance was considered more appropriate for estimating the flow in Baker Canal East. The flow for Baker Canal East that was calculated from the mass balance (35 cfs) seemed reasonable considering that the flow that was estimated in Baker Canal East on the previous day (June 3) was approximately 70 cfs (shown in Table C6.2).

The inflows and outflows from tributaries and distributaries were based on direct measurements of flow or flows estimated from drogue velocities.

The total inflow needed near the downstream end of the system was based on the average of an acoustic Doppler flow measurement at BCh-3 and a flow estimated from a drogue velocity at BCh-4. These were the measurements that were closest to the downstream end.

The total quantity of incremental inflow that was needed was calculated by subtracting the headwater and tributary inflows from the total amount of flow needed near the downstream end. The incremental inflow was assumed to enter the modeled stream reaches at a uniform rate per length of stream.

4.2.12 Incremental Inflow, Data Types 16, 17, and 18

The incremental flow rates were calculated as described in Section 4.2.11. The values used for model inputs for the incremental inflows are shown in Table E.5. The water quality values were obtained by averaging the observed water quality data from four tributary stations (SJC-1, SJC-2, GB-1, and DBC-1).

4.2.13 Nonpoint Source Loads, Data Type 19

Nonpoint source loads which were not associated with a flow are input into this part of the model. These loads can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, CBODu loads, and NBODu loads. These loads were used as calibration parameters and adjusted to get the model to match observed data. The values used for the model input data for nonpoint source loads are shown in Table E.5 in Appendix E.

4.2.14 Headwaters, Data Types 20, 21, and 22

Headwater inputs were specified for Baker Canal East and Bayou Verret. The headwater flow rates were calculated as described in Section 4.2.11. The water quality for the headwaters was based on observed data at stations BV-1 and BkC-1. The headwater DO values were based on daily average DO values for the sampling day from continuous monitoring data at BV-1 and BkC-1. Calculations for daily minimum and daily average DO from continuous monitoring data are shown in Appendices H1 and H2. The values used for model inputs for the headwaters are shown in Table E.6 in Appendix E.

4.2.15 Wasteloads, Data Types 24, 25, and 26

No point source discharges were simulated in the model because the existing point sources are small and distant from the modeled waterbody. Three tributaries (St. James Canal Western, St. James Canal Eastern, and Dregeboat Canal) and one distributary (Grand Bayou) were specified as wasteloads in the model. The flow rates for these tributaries and distributaries were calculated as described in Section 4.2.11. Water quality inputs for the tributaries were based on observed data for stations SJC-1, SJC-2, and DBC-1. The values used for model inputs for the wasteloads are shown in Table E.7 in Appendix E.

4.2.16 Lower Boundary Conditions, Data Type 27

Because dispersion was explicitly simulated in the model, inputs were specified for lower boundary conditions. The values for temperature, salinity, conductivity, and DO were based on averages of observed data collected by a continuous monitor at station LDA-1 during the intensive survey. The CBODu and NBODu values were calculated from the GSBOD spreadsheet provided by LDEQ based on water quality samples taken at LDA-1. The model inputs for the lower boundary conditions are summarized in Table E.8 in Appendix E.

4.3 Model Discussion and Results

4.3.1 Simulation of Chloride and Conductivity

Before calibrating the water quality, the model predictions for chloride and conductivity were examined to evaluate the flow balance. Plots of predicted and observed chloride and conductivity are shown in Appendix I.

The predicted values of chloride and conductivity follow the pattern of the observed data, which is a general increase from Baker Canal East to Bayou Citamon to Bayou Chevreuil. The model tended to underpredict chloride and conductivity in the downstream half of the system. This indicates that the actual concentrations of chloride and conductivity in the incremental inflow may be higher towards the downstream end of the system (spatially constant concentrations were used in the model).

4.3.2 Water Quality Calibration Results

Plots of predicted and observed values of CBODu, NBODu, and DO are shown in Appendix J. A printout of the tabular model output is included in Appendix K. Plots of predicted and observed DO are also shown in Figures 4.2 and 4.3.

In general the calibration results for CBODu and NBODu were good. The model did not consistently underpredict or overpredict the NBODu and CBODu (i.e., no consistent bias).

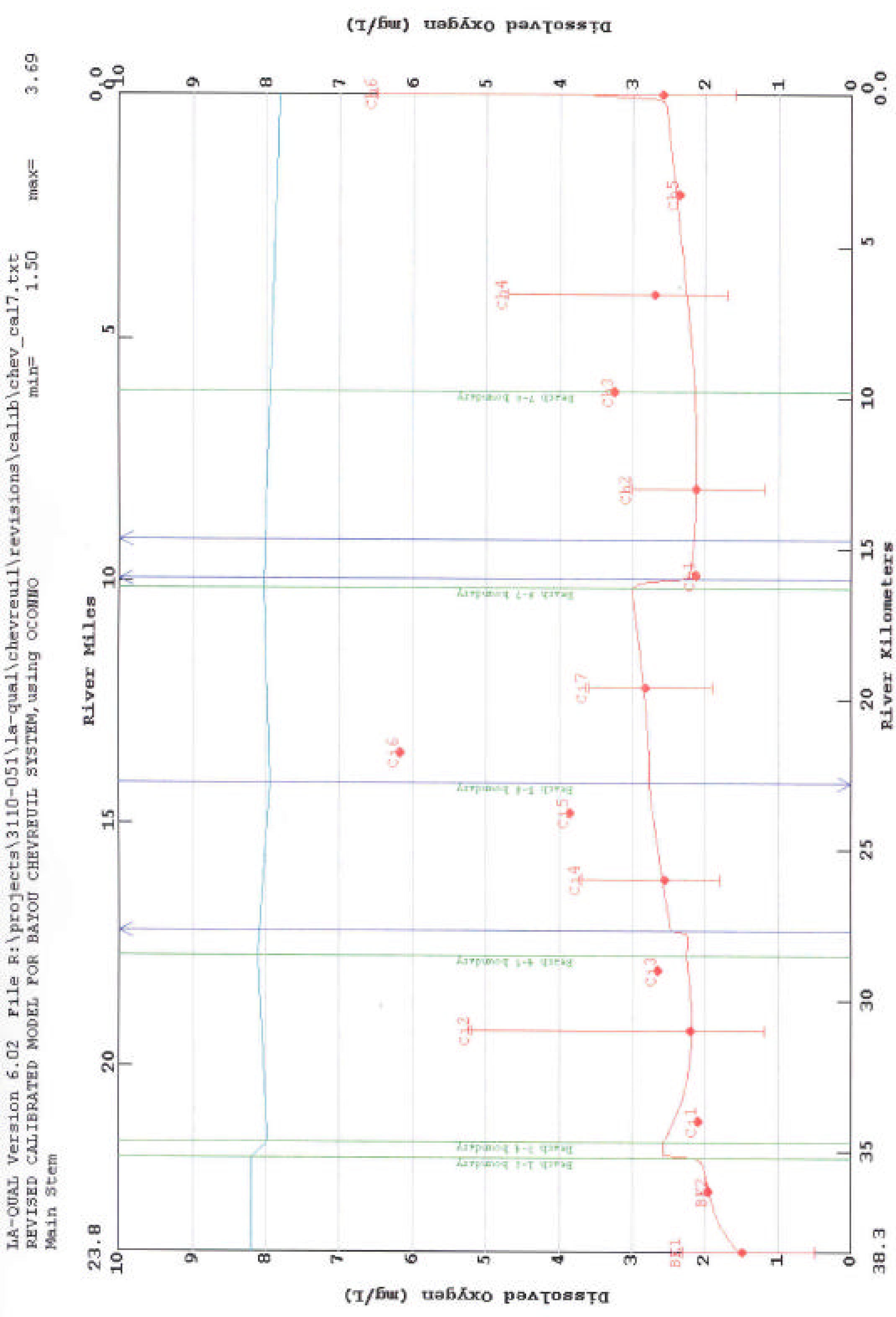

Figure 4.2. Predicted and observed DO for Main Stem calibration

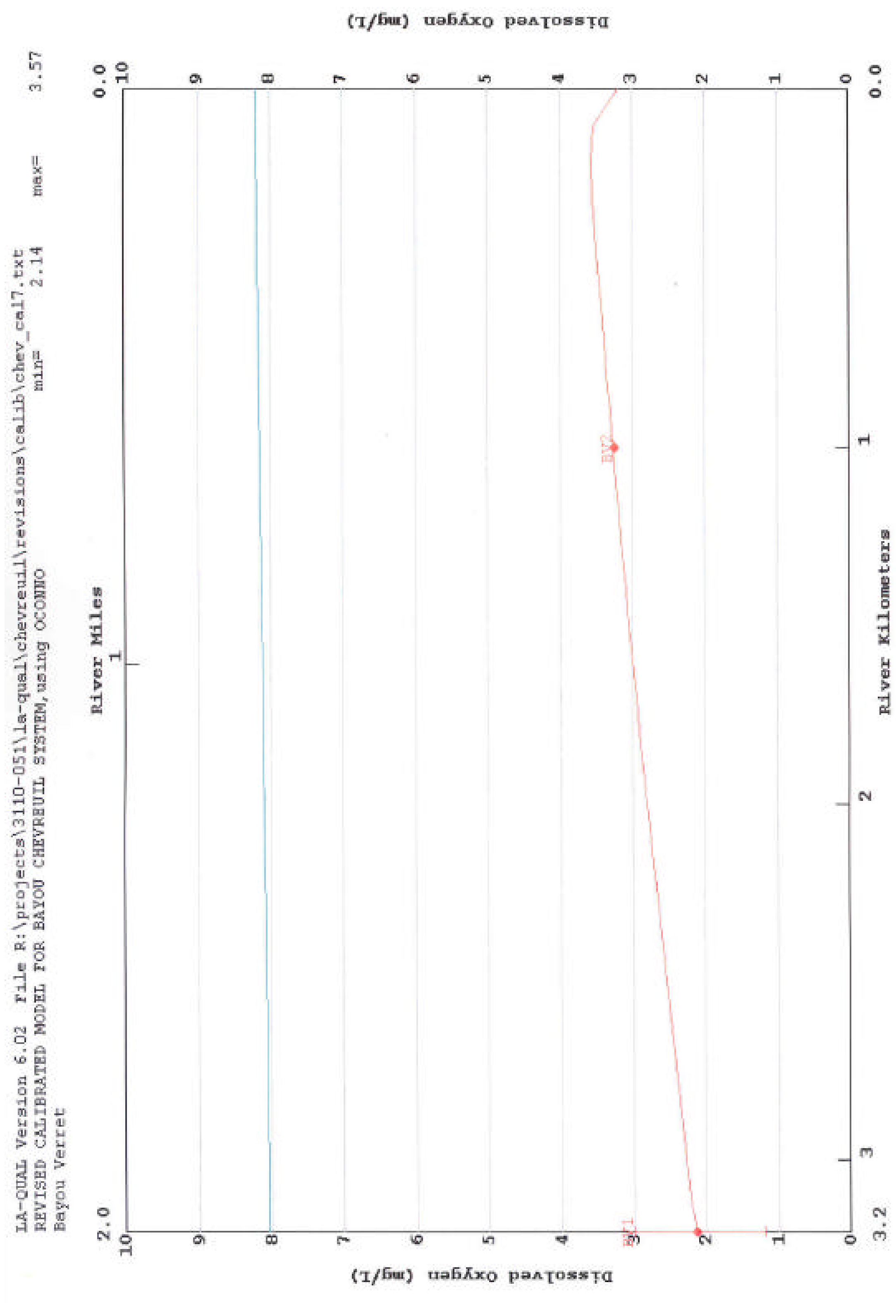

Figure 4.3. Predicted and observed DO for Bayou Verret calibration

According to recent LDEQ policy, the DO calibration target at each station was set as shown below based on the diurnal DO fluctuations from the continuous monitoring data:

Diurnal DO fluctuation < 2 mg/L:	daily average DO
Diurnal DO fluctuation 2-9 mg/L:	1 mg/L above daily minimum DO

The diurnal DO fluctuations were determined from continuous monitoring data collected on the day of the water quality sampling (June 4). For each station without continuous monitoring data, the daily average and daily minimum DO were estimated using continuous monitoring data from a nearby station along the main stem. The ratio of the instantaneous DO to daily average (or daily minimum) DO at each continuous monitoring station was calculated for 15 minute intervals throughout the day. Then each instantaneous DO at a station without continuous monitoring was divided by the ratio corresponding to the time at which the instantaneous value was measured (see calculations in Appendices H1 and H2).

The calibration results for DO were acceptable. The predicted DO values were similar to the calibration targets at stations with the lowest observed DO values. The model could not be calibrated to accurately match all of the DO calibration targets without specifying unreasonable values for model inputs. The emphasis was placed on matching the lower DO calibration targets so that that the model would provide a more accurate prediction of the minimum DO values along the length of the stream (which is what effects the load reductions that are needed for the projection simulations). The station with the largest difference between predicted and observed values was BCi-6, which had an estimated minimum DO that was much higher than other stations.

5. Water Quality Projections

Since the calibrated model indicated that the DO criterion was not being met, no-load scenarios were performed in addition to the traditional summer and winter projections.

5.1 Critical Conditions, Seasonality and Margin of Safety

The Clean Water Act requires the consideration of the seasonal variation of the conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL.

Critical conditions for dissolved oxygen were determined by calculating 90th percentile temperatures for each season for subsegment 020101 using long term water quality data from the LDEQ Ambient Monitoring Network. The 90th percentile temperatures were calculated using recorded values from station 0084 ("Bayou Chevreuil near Chegby (Chackbay), LA"). These calculations are shown in Appendix L.

Graphical and regression analysis techniques have been used by LDEQ historically to evaluate the temperature and dissolved oxygen data from the Ambient Monitoring Network and run-off determinations from the Louisiana Office of Climatology water budget. Since nonpoint loading is conveyed by run-off, this was a reasonable correlation to use. Temperature is strongly inversely proportional to dissolved oxygen and moderately inversely proportional to run-off. Dissolved oxygen and run-off are also moderately directly proportional. The analysis concluded that the critical conditions for stream dissolved oxygen concentrations were those of negligible nonpoint run-off and low stream flow combined with high stream temperature.

When the rainfall run-off (and non-point loading) and stream flow are high, turbulence is higher due to the higher flow and the temperature is lowered by the run-off. In addition, run-off coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. Reaeration rates and DO saturation are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and dissolved oxygen but not necessarily periods of high BOD decay.

This phenomenon is interpreted in TMDL modeling by assuming that nonpoint loading associated with flows into the stream are responsible for the benthic blanket which accumulates on the stream bottom and that the accumulated benthic blanket of the stream, expressed as SOD and/or resuspended BOD in the calibration model, has reached steady state or normal conditions over the long term and that short term additions to the blanket are off set by short term losses. This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher. The only mechanism for changing this normal benthic blanket condition is to implement best management practices and reduce the amount of nonpoint source loading entering the stream and feeding the benthic blanket.

Critical season conditions were simulated in the dissolved oxygen TMDL projection modeling by using the default flows from the Louisiana Technical Procedures Manual (LTP), and the 90th percentile temperatures. Incremental inflow was assumed to be zero; model loading was from perennial tributaries, sediment oxygen demand, and resuspension of sediments.

In reality, the highest temperatures occur in July-August, the lowest stream flows may occur in other months, and the maximum nonpoint source loading occurs following a significant rainfall, i.e., high-flow conditions. The summer projection model is established as if all these conditions happened at the same time. The winter projection model accounts for the seasonal differences in flows and BMP efficiencies. Other conservative assumptions regarding rates and loadings are also made during the modeling process. In addition to the conservative measures, an explicit MOS of 20% was used for all manmade loads to account for future growth, safety, model uncertainty, and data inadequacies.

5.2 Input Data Documentation

The values and sources of the input data used for the summer projection, summer no load, winter projection, and winter no load scenarios are shown in Appendix M. Except as mentioned below, the projection inputs were unchanged from the calibration.

5.2.1 Initial Conditions, Data Type 11

The initial temperatures were set to the 90th percentile temperature for each season in accordance with the LTP. The initial DO and salinity values were unchanged from the calibration.

5.2.2 SOD and Nonpoint Sources, Data Types 12 and 19

The nonpoint source values were calculated for each projection scenario using a load equivalent spreadsheet. An analysis was made of the calibration nonpoint source and SOD loads in terms of total loading in units of g O_2/m^2/day and compared to the reference stream loads in the same terms (which accounted for the width differences between the reference and the modeled streams). All of the calibration values were larger than reference stream values. The same spreadsheet also calculated load reductions for the headwaters.

LDEQ has collected and measured the CBOD and NBOD oxygen demand loading components for a number of years. These loads have been found in all streams including the non-impacted reference streams. It is LDEQ’s opinion that much of this loading is attributable to runoff loads which are flushed into the stream during runoff events, and subsequently settle to the bottom in the slow moving streams. These benthic loads decay and breakdown during the year, becoming easily resuspended into the water column during the low flow/high temperature season. This season has historically been identified as the critical dissolved oxygen season.

LDEQ simulates part of the nonpoint source oxygen demand loading as resuspended benthic load and SOD. The calibrated nonpoint loads (CBODu, NBODu, and SOD) are summed to produce the total calibrated benthic load. The total calibrated benthic load is then reduced by the total background benthic load (determined from LDEQ's reference stream research) to determine the total manmade benthic loading. The manmade portion is then reduced incrementally on a percentage basis to determine the necessary percentage reduction of manmade loading required to meet the water body's dissolved oxygen criteria. These reductions are applied uniformly to all reaches sharing similar hydrology and land uses.

Following the same protocol as the point source discharges, the total reduced manmade benthic load is adjusted for the margin of safety by dividing the value by one minus the margin of safety. This adjusted load is added back to the total background benthic value to obtain the total projection model benthic load. This total projection benthic load is then broken out into its components of SOD, resuspended CBOD, and resuspended NBOD by multiplying the total projection benthic load by the ratio of each calibrated component to the total calibrated benthic load.

LDEQ has found variations in the breakdown of the individual CBOD and NBOD components. While the total BOD is reliable, the carbonaceous and nitrogenous component allocation is subject to the type of test method. In the past, LDEQ used a method which suppressed the nitrogenous component to obtain the carbonaceous component value, which was then subtracted from the total measured BOD to determine the nitrogenous value. The suppressant in this method was only reliable for twenty days thus leading to the assumption that the majority of the carbonaceous loading was depleted within that period of time. The test results supported this assumption. Recently the suppressant started failing around day seven and the manufacturer of the suppressant will only guarantee its potency for a five day period. LDEQ felt a five day test would not adequately depict the water quality of streams and began a search for a new test method. The research found a new proposed method for testing long term BODs in Standard Methods.

This proposed method is a sixty day test which measures the incremental total BOD of the sample while at the same time measuring the increase in nitrite/nitrate in the sample. This increase in nitrite/nitrate allows LDEQ to calculate the incremental nitrogenous portion by multiplying the increase by 4.57 to determine the NBOD daily readings. These NBOD daily readings are then subtracted from the daily readings for total BOD to determine the CBOD daily values. A curve fit algorithm is then applied to the daily component readings to obtain the estimated ultimate values of each component as well as the decay rate and lag times of the first order equations.

LDEQ has implemented the new test method over the last several survey seasons. The results obtained using the new method showed that a portion of the CBOD first order equation does begin to level off prior to the twentieth day; however a secondary CBOD component begins to use dissolved oxygen sometime between day ten and day twenty-five. This secondary CBOD component was not being assessed as CBOD using the previous method but was being included in the NBOD load. Thus the CBOD and NBOD component loading used in the reference stream studies is not consistent with the results using the new proposed 60 day method and the individual values should not be used to determine background values for samples processed using the new test method. However, the sum of CBOD and NBOD should be about the same for both new and old test methods. For this reason, background values in this model are based on the sum of reference stream benthic loads.

LDEQ's reference stream data were examined to identify reference streams that might be applicable for estimating background loads for the Bayou Chevreuil system. Although none of the reference streams is located in or near the Barataria basin, four reference streams were identified as having some characteristics (i.e., sediment type, depth, velocity) similar to streams in this subsegment. The nonpoint source loads estimated by LDEQ for these four reference streams are shown in Table 5.1 below. Based on previous experience with DO TMDLs in Louisiana, the total nonpoint source loads for Saline Bayou and Beaucoup Bayou (3.9 to 4.0 g/m^2/day) seemed unreasonably high as estimates of background loading for this subsegment. Therefore, the background load for this subsegment was set to 2.0 g/m^2/day based on the estimated loads for Big Roaring Bayou and Indian Bayou.

Background concentrations of CBODu and NBODu in the headwaters were also estimated based on LDEQ's reference stream data. Concentrations of CBODu and NBODu in these four reference streams are shown in Table 5.1. The concentrations were lower for Saline Bayou than for the other three streams, which could be due to the fact that Saline Bayou had more flow than the other three streams. Because the Bayou Chevreuil system has very little advective flow during critical conditions, the background concentrations for the Bayou Chevreuil system were based on values for Big Roaring Bayou, Indian Bayou, and Beaucoup Bayou (all of which were not flowing during the surveys). Based on data for these three streams, a concentration of 9 mg/L of total BODu (i.e., sum of CBODu and NBODu) was selected as the background value. However, the LDEQ TMDL spreadsheet requires individual concentrations of CBODu and NBODu. Therefore, the background concentration of total BODu was divided between CBODu and NBODu based on the ratio of CBODu to NBODu for each inflow in the calibration.

Table 5.1. Data from selected LDEQ reference streams (Smythe 1999).

	Big Roaring Bayou	Indian Bayou	Beaucoup Bayou	Saline Bayou Site 2-3
Sediment type	silt	silt	silt	silt
Velocity during survey (m/sec)	0.00	0.00	0.00	0.23
Depth during survey (m)	1.08	0.64	0.67	0.93
NPS CBODu load (g/m^2/day)	0.688	0.218	0.169	0.531
NPS NBODu load (g/m^2/day)	0.095	0.090	0.498	1.637
SOD at 20°C (g/m^2/day)	1.45	1.52	4.20	2.25
Temperature during survey (°C)	20.15	20.82	16.45	16.11
SOD at stream temp. (g/m^2/day)	1.46	1.60	3.36	1.76
Total NPS load (g/m^2/day)	2.24	1.91	4.03	3.93
CBODu concentration (mg/L)	3.48	2.94	2.72	1.60
NBODu concentration (mg/L)	5.41	7.26	5.80	3.70

5.2.3 Incremental Inflow, Data Types 16, 17, and 18

The incremental inflows were set to zero to simulate critical low flow conditions (as discussed in section 5.1).

5.2.4 Headwaters, Data Types 20, 21, and 22

Since there were no USGS flow gages and no published 7Q10 values for this subsegment, the flow rate for each headwater was set to 0.1 cfs (0.003 m^3/sec) for summer and 1.0 cfs (0.03 m^3/sec) for winter as specified in the LTP. Headwater concentrations of CBODu and NBODu were set based on background concentrations and percent reduction calculations in the spreadsheets discussed in Section 5.2.2.

For the projections for the Bayou Chevreuil system, it was assumed that reductions of CBODu and NBODu in headwater and tributary inflows would also result in improvements in the DO concentrations of those inflows. Therefore, the DO concentrations for headwater and tributary inflows were set assuming that measured values from the survey (adjusted to daily averages) represented no reduction of nonpoint sources, 90% saturation represented complete reduction of manmade nonpoint sources, and 100% saturation represented complete reduction of manmade and natural nonpoint sources. Calculations for the inflow DO values used in the model are presented in Table M.21 (Appendix M).

5.2.5 Wasteloads, Data Types 24, 25, and 26

Since there were no USGS flow gages and no published 7Q10 values for this subsegment, the flow rate for each tributary in the model was set to 0.1 cfs (0.003 m^3/sec) for summer and 1.0 cfs (0.03 m^3/sec) for winter as specified in the LTP. Headwater concentrations of CBODu and NBODu were set based on background concentrations and percent reduction calculations in the spreadsheets discussed in Section 5.2.2. The tributary DO concentrations were set in the same manner as for the headwaters (as described in Section 5.2.4).

5.2.6 Lower Boundary Conditions, Data Type 27

The temperatures for the lower boundary conditions were set equal to the 90th percentile temperature for each season. The DO values were set following the same methodology as for other boundaries in the model (i.e., headwater and tributaries; see Section 5.2.4). This methodology was used for the lower boundary because it was assumed that nonpoint source load reductions in the Bayou Chevreuil and Bayou Boeuf watersheds would improve the water quality in the southwest corner of Lac des Allemands. The CBODu and NBODu concentrations were reduced from the calibration values using the LDEQ TMDL spreadsheet in the same way as for the headwaters and tributaries. The other lower boundary inputs were unchanged from the calibration.

5.3 Model Discussion and Results

5.3.1 No Load Scenarios

The summer and winter no load scenarios were run to predict DO concentrations with no manmade sources under critical conditions. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix N. Graphs of the predicted DO and printouts of the tabular output are presented in Appendix O.

The minimum predicted DO values from the no load scenarios were 3.0 mg/L for summer and 5.5 mg/L for winter. In other words, these simulations showed that complete elimination of man-made sources would result in DO values well below the current standard during summer and slightly above the standard during winter. Based on these results, the current DO standard should definitely be reevaluated for summer and may need to be reevaluated for winter.

5.3.2 Summer and Winter Projections

The summer and winter projection simulations were run to determine the allowable loadings and percent reductions for the Bayou Chevreuil system that would result in the existing DO standard being maintained. Printouts of the spreadsheets with nonpoint source load calculations for these scenarios are presented in Appendix P. Graphs of the predicted DO and printouts of the tabular output for these scenarios are presented in Appendix Q. Graphs of the predicted DO are also shown in Figures 5.1 through 5.4.

As shown in Table 5.2, the load reductions that were required for the model to show the DO standard being met included both a complete elimination of man-made nonpoint sources plus some reduction of background nonpoint sources in the summer. For each scenario, a uniform percent reduction was applied to all reaches in the model because the hydrology and land uses appeared to be similar for all reaches.

Table 5.2. Summary of nonpoint source load reductions required to meet the DO standard.

	Man-made nonpoint sources	**Background nonpoint sources**
Summer (May – October)	100%	46%
Winter (November – April)	98%	0%

5.4 Calculated TMDL, WLAs, and LAs

5.4.1 Outline of TMDL Calculations

An outline of the TMDL calculations is provided below to assist in understanding the TMDL calculations, which are shown in Appendix P. Slight variances may occur based on individual cases. All of the TMDL calculations were done using the LDEQ TMDL spreadsheet.

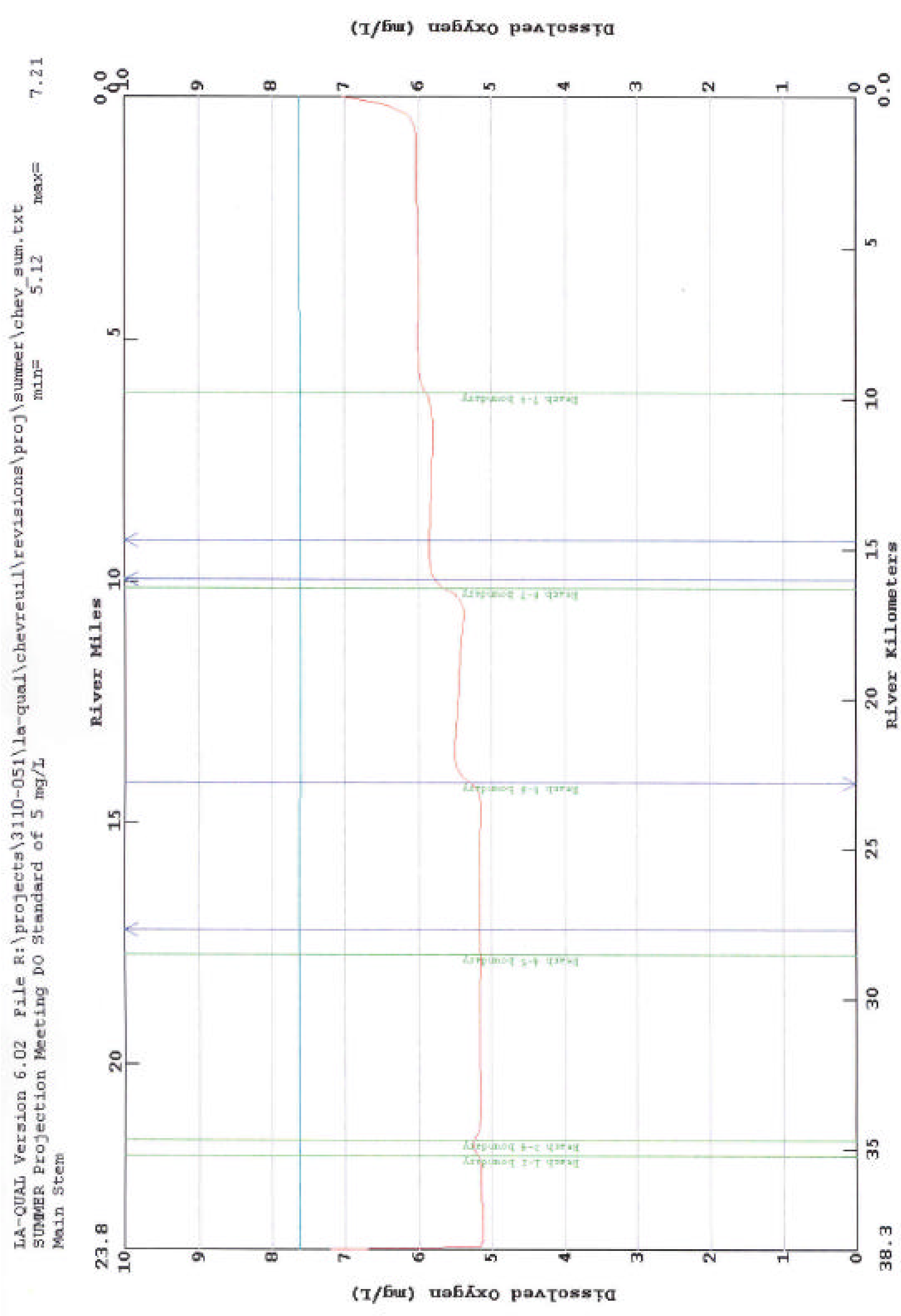

Figure 5.1. Predicted DO for Main Stem summer projection

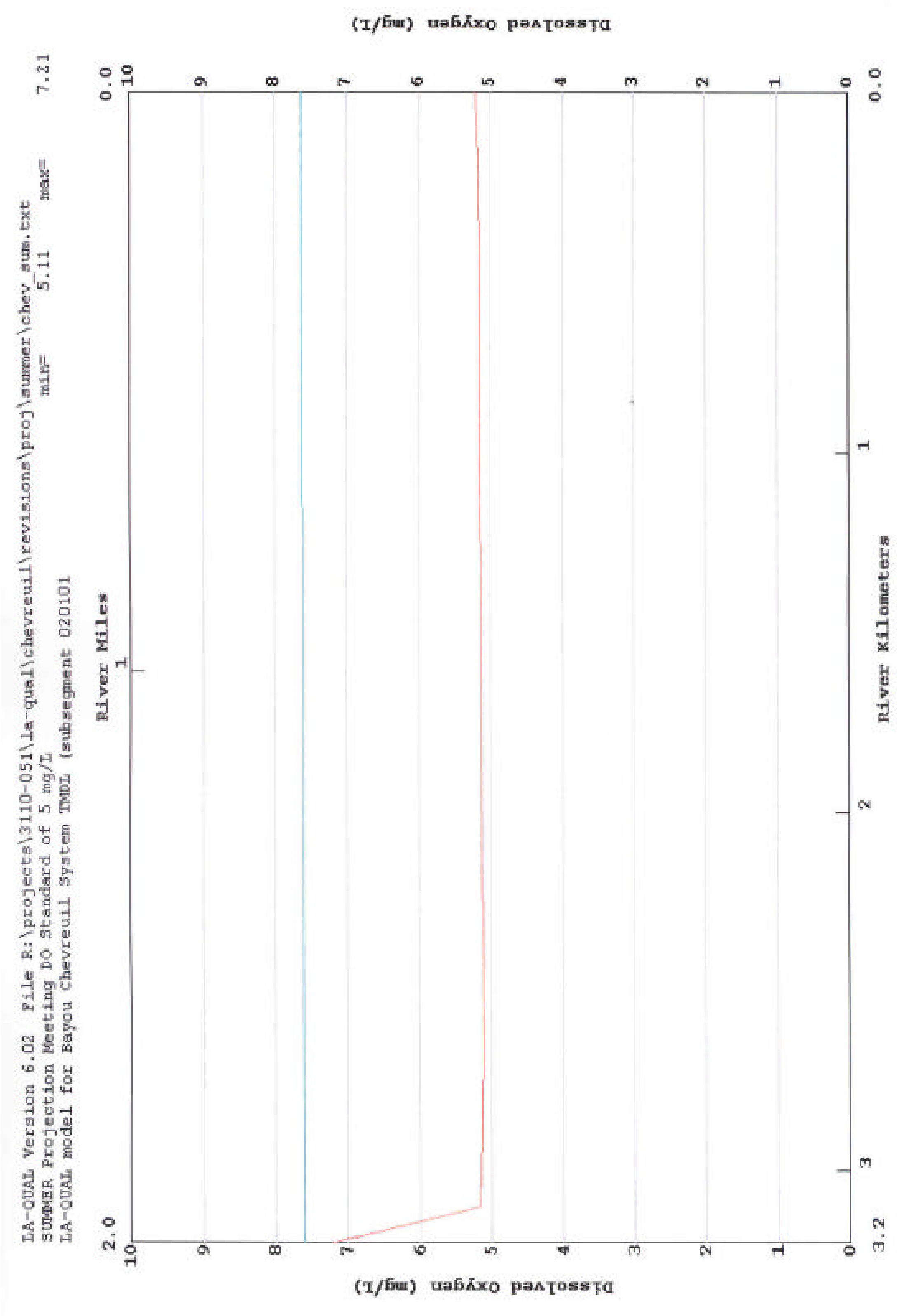

Figure 5.2. Predicted DO for Bayou Verret summer projection

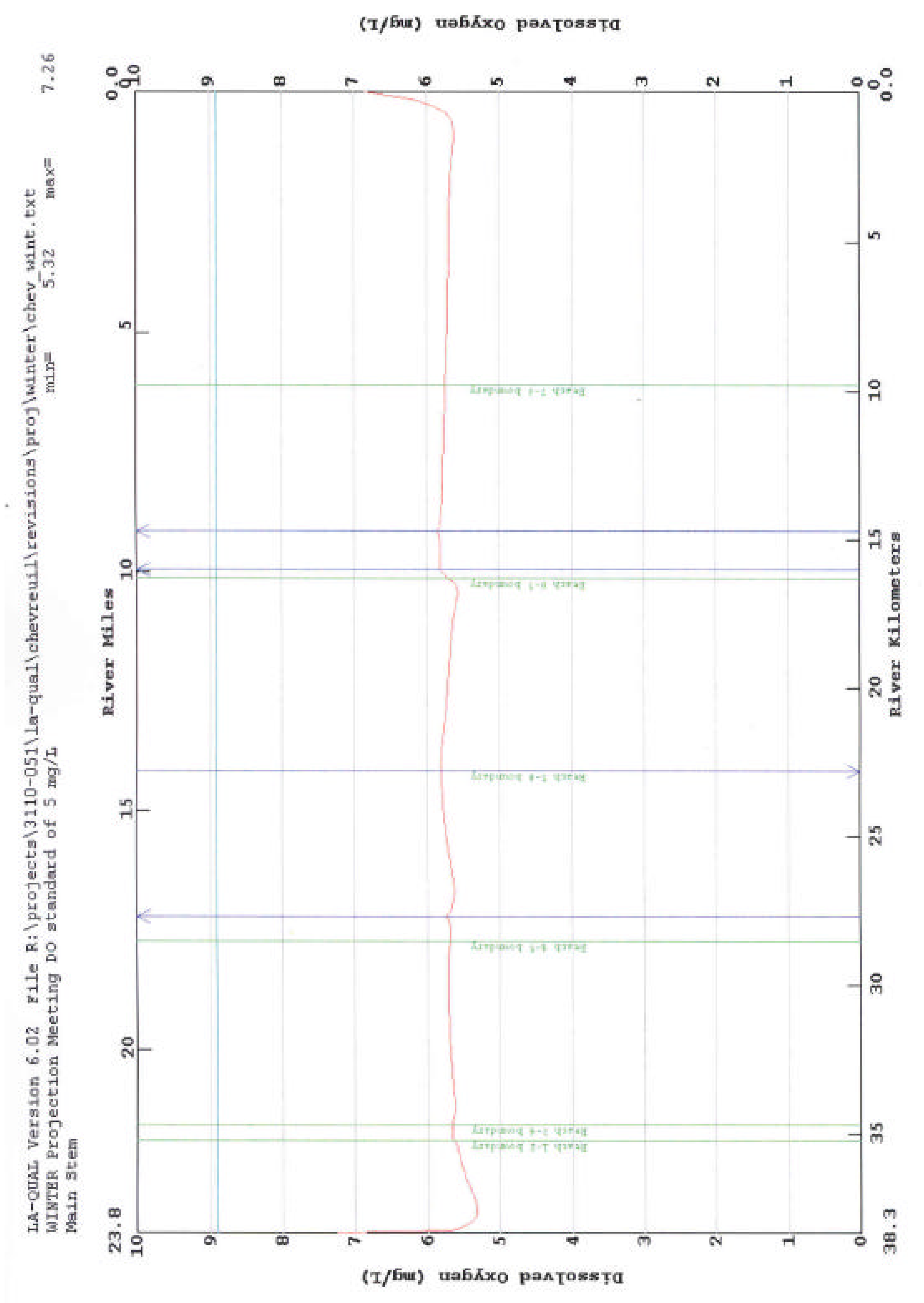

Figure 5.3. Predicted DO for Main Stem winter projection

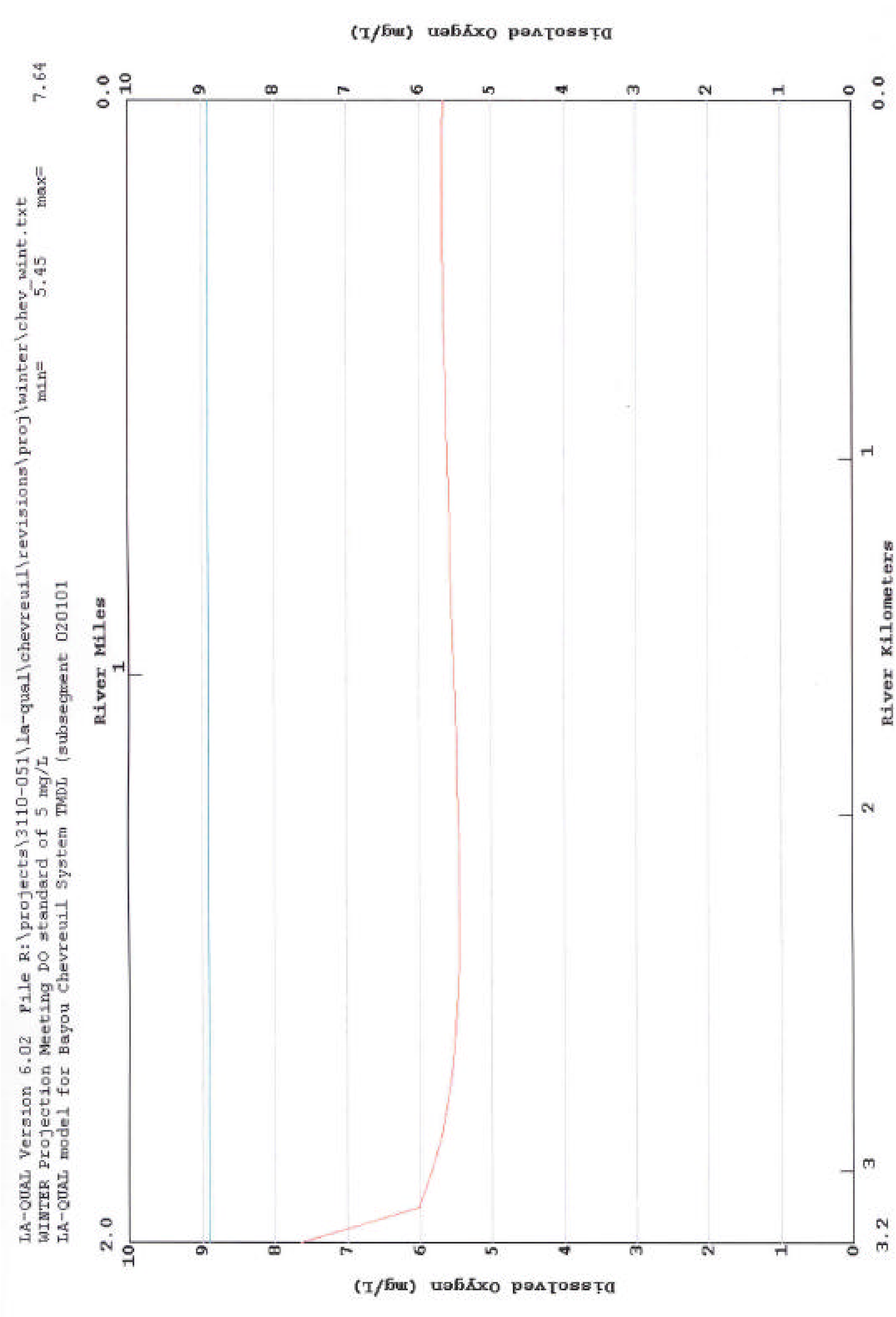

Figure 5.4. Predicted DO for Bayou Verret winter projection

A) The natural background benthic loading was estimated from reference stream resuspension (nonpoint CBOD and NBODu) and SOD load data.

B) The calibration man-made benthic loading was determined as follows:

- Calibration resuspension and SOD loads were summed for each reach as g/m^2/day of oxygen demand to get the calibration benthic loading.

- The natural background benthic loading was subtracted from the calibration benthic loading to obtain the man-made calibration benthic loading.

C) Projection benthic loads are determined by trial and error during the modeling process using a uniform percent reduction for resuspension and SOD. Although no point sources were modeled, the design flows of the point sources that were included in the TMDL were increased to obtain an explicit MOS of 20%. Headwater and tributary concentrations of CBODu, NBODu, and DO range from reference stream levels to calibration levels based on the characteristics of the headwater. Where headwaters and tributaries exhibit man-made pollutant loads in excess of reference stream values, the loadings are reduced by the same uniform percent reduction as the benthic loads.

- The projection benthic loading at 20^{o}C is calculated as the sum of the projection resuspension and SOD components expressed as g/m^2/day of oxygen demand.

- The natural background benthic load is subtracted from the projection benthic load to obtain the man-made projection benthic load for each reach.

- The percent reduction of man-made loads for each reach is determined from the difference between the projected man-made nonpoint load and the man-made nonpoint load found during calibration.

- The projection loads are also computed in units of lbs/day and kg/day for each reach.

D) The total stream loading capacity at critical water temperature is calculated as the sum of:

- Headwater and tributary CBODu and NBODu loading in lbs/day and kg/day.

- The natural and man-made projection benthic loading for all reaches of the stream is converted to the loading at critical temperature and summed in lbs/day and kg/day.

- Point source CBODu and NBODu loading in lbs/day and kg/day.

- The margin of safety in lb/day and kg/day.

5.4.2 Results of TMDL Calculations

The TMDL for the biochemical oxygen demanding constituents (CBODu, NBODu, and SOD) was calculated for the summer and winter critical seasons. Printouts of the TMDL spreadsheets are presented in Appendix P. A summary of the loads is presented in Table 5.3.

The nonconservative behavior of dissolved oxygen allows many small to remote point source dischargers to be assimilated by their receiving waterbodies before they reach the modeled waterbody. These dischargers are said to have very little to no impact on the modeled waterbody and therefore, they are not included in the model and are not subject to any reductions based on this TMDL. These facilities are permitted in accordance with state regulation and policies that provide adequate protective controls. New similarly insignificant point sources will continue to be issued permits in this manner. Significant existing point source dischargers are either included in the model or are determined to be insignificant by other modeling. New significant point source dischargers would have to be evaluated individually to determine what impact they have on the impaired waterbody and the appropriate controls.

The point source wasteload allocation (WLA) includes loads from all permitted point sources within the subsegment that are known to discharge oxygen demanding effluent. For this subsegment, none of the point sources were included in the model because they are small and far away from the modeled waterbodies. Their loads were accounted for in the model by calibration as part of the boundary conditions or nonpoint source loading.

The LDEQ TMDL spreadsheet applies a user-specified explicit MOS to the point source loads and to the man-made nonpoint source loads (i.e., all man-made sources). The explicit MOS that was specified in the spreadsheet was 20%. For summer, this TMDL required a complete elimination of the man-made nonpoint source loads, thereby eliminating the need for a MOS for that portion of the load for summer.

It should be noted that the 20% explicit MOS accounts for future growth as well as uncertainties associated with the modeling process. The TMDL also includes an implicit MOS created by conservative assumptions in the modeling (see Section 5.1).

Table 5.3. TMDL for Subsegment 020101 (sum of CBODu, NBODu, and SOD).

	Load (kg/day) for:	
	Summer (May-Oct)	**Winter (Nov-Apr)**
Point Source WLA	7	7
Point Source Reserve MOS	2	2
Natural Nonpoint Source LA	2321	3091
Man-made Nonpoint Source LA	0	49
Man-made Nonpoint Source MOS	0	12
TMDL	2330	3161

6. Sensitivity Analysis

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The LA-QUAL model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the calibration scenario. Parameters were varied by +/- 30%, except temperature, which was adjusted +/- 2 degrees Centigrade. The results of the sensitivity analysis are summarized in Tables 6.1.

The model predictions for minimum DO were most sensitive to headwater DO because the minimum DO was occurring at the upstream end of Baker Canal East. The model output for minimum DO was not sensitive to tributary and incremental inflow parameters and lower boundary conditions.

Table 6.1. Summary of calibration model sensitivity analysis.

Parameter	**Negative Parameter Changes**			**Positive Parameter Changes**		
	Parameter Change	**Minimum DO (mg/L)**	**Percentage Difference in DO**	**Parameter Change**	**Minimum DO (mg/L)**	**Percentage Difference in DO**
Headwater DO	-30%	1.17	-25.0%	30%	1.94	24.4%
Stream Depth	-30%	1.65	5.8%	30%	1.49	-4.5%
Stream Reaeration	-30%	1.50	-3.8%	30%	1.61	3.2%
Benthal Demand (SOD)	-30%	1.59	1.9%	30%	1.53	-1.9%
Stream Velocity	-30%	1.53	-1.9%	30%	1.57	0.6%
Headwater Flow	-30%	1.53	-1.9%	30%	1.56	0.0%
Initial Temperature	-2°C	1.57	0.6%	2°C	1.53	-1.9%
Headwater CBOD	-30%	1.56	0.0%	30%	1.55	-0.6%
Headwater NBOD	-30%	1.56	0.0%	30%	1.55	-0.6%
CBOD Decay Rate	-30%	1.56	0.0%	30%	1.55	-0.6%
NBOD Decay Rate	-30%	1.56	0.0%	30%	1.55	-0.6%
Incremental DO	30%	1.55	-0.6%	30%	1.56	0.0%
Incremental Flow Rate	-30%	1.55	-0.6%	30%	1.56	0.0%
Incremental CBOD	-30%	1.56	0.0%	30%	1.56	0.0%
Incremental NBOD	30%	1.56	0.0%	30%	1.56	0.0%
Wasteload DO	-30%	1.56	0.0%	30%	1.56	0.0%
Wasteload Flow	-30%	1.56	0.0%	30%	1.56	0.0%
Wasteload CBOD	-30%	1.56	0.0%	30%	1.56	0.0%
Wasteload NBOD	-30%	1.56	0.0%	30%	1.56	0.0%
Lower Boundary DO	-30%	1.56	0.0%	30%	1.56	0.0%
Lower Boundary CBOD	-30%	1.56	0.0%	30%	1.56	0.0%
Lower Boundary NBOD	-30%	1.56	0.0%	30%	1.56	0.0%

7. Conclusions

The summer projection required man-made loads to be completely eliminated and background loads to be reduced by 46% while the winter projection required man-made loads to be reduced by 98% to maintain a minimum DO of 5.0 mg/L during critical conditions.

This subsegment was listed as impaired due to nutrients as well as organic enrichment / low DO. This TMDL establishes load limitations for oxygen-demanding substances and goals for reduction of those pollutants. LDEQ's position, as stated in the declaratory ruling issued by Dale Givens regarding water quality criteria for nutrients (Sierra Club v. Givens, 710 So.2d 249 (La. App. 1st Cir. 1997), writ denied, 705 So.2d 1106 (La. 1998), is that when oxygen-demanding substances are controlled and limited in order to ensure that the dissolved oxygen criterion is supported, nutrients are also controlled and limited. The implementation of this TMDL through wastewater discharge permits and implementation of best management practices to control and reduce runoff of soil and oxygen-demanding pollutants from nonpoint sources in the watershed will also control and reduce the nutrient loading from those sources.

This TMDL has been developed to be consistent with the State antidegradation policy (LAC 33:IX.1109.A).

LDEQ will work with other agencies such as local Soil Conservation Districts to implement nonpoint source best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a four-year cycle. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the four-year cycle. Sampling is conducted on a monthly basis to yield approximately 12 samples per site each year the site is monitored. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, approximately one half of the state's waters are newly assessed for 305(b) and 303(d) listing purposes for each biennial cycle with sampling occurring statewide each year. The four-year cycle follows an initial five-year rotation which covered all basins in the state according to the TMDL priorities. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list.

8. References

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